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A COMPARISON BETWEEN ELECTRIC FIELD STRENGTHS SIMILARLY GENERAT--ETC(U)

FEB 80   M DEW, F HARRISON

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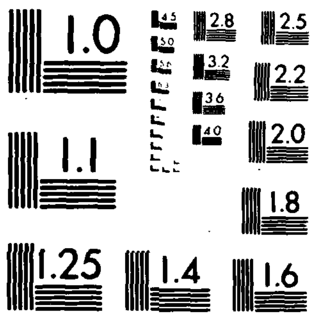
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LEVEL II

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MEMORANDUM No. 3248

ROYAL SIGNALS & RADAR ESTABLISHMENT

AD A093462

A COMPARISON BETWEEN ELECTRIC FIELD STRENGTHS SIMILARLY GENERATED AND MEASURED IN THE OPEN AIR, IN A SHIELDED ENCLOSURE AND IN A LARGE AIRCRAFT HANGAR, OVER FREQUENCY RANGE 10 TO 110 MHz

Authors: M Dew and F Harrison

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ROYAL SIGNALS AND RADAR ESTABLISHMENT

Memorandum 3248

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(12) 28

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SUMMARY

A difficulty found in some electromagnetic compatibility (EMC) measurements is illustrated by showing that a particular measurement yields significantly different results when performed in a certain shielded enclosure compared with those yielded when performed in the open air. It is also shown that when performed in a large aircraft hangar the results are tolerably the same as those yielded in the open air. On these facts it is suggested that a worthwhile use for an aircraft hangar no longer devoted to its original use would be to assign it wholly or in part as a location for EMC measurement work. Further, a large shielded enclosure is likely to provide results more in agreement with open air measurements than would a small enclosure similarly used.

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RSRE MEMORANDUM 3248

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M Dew and F Harrison

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TERMINOLOGY

The Appendix defines some of the terms used.

INTRODUCTION

This memorandum stems from an investigation done in 1977.

Among parameters frequently measured for EMC purposes during development of equipments are:-

i Levels of spurious emission radiated.

ii Levels of incident radiated emission just causing onset of susceptibility.

Both types of measurement are made over bands of radio frequency required by the relevant equipment specification. There is widespread use of shielded enclosures in the performance of such EMC measurements because it is frequently difficult to measure emissions in the open air or in a factory area due to the levels of other signals simultaneously received (eg from broadcasting stations) and because it is usually undesirable unrestrictedly to radiate the locally generated signals needed to examine the onset of susceptibility. It is found, however, that when any particular layout of equipment is used to generate an rf emission inside a shielded enclosure and measure its electric field strength therein, the value measured usually differs and often substantially differs (eg by 30 to 40 dB) from the value which would have been yielded by the same layout if set up in the open air (1).

Different shielded enclosures yield different deviations from open air values. Thus an impossible task faces the specification writer who, without

knowing the shielded enclosure to be used wishes to specify limits of emission and onset of susceptibility to accurately correspond with particular limits in open air performance. This situation has led to some use of anechoic chambers (2) for EMC measurements, to attempts to devise methods of use of shielded enclosures to give results tolerably the same as open air measurement (3) (4) (5) or to produce an alternative shielded measuring space working differently from and more predictably than the conventional enclosure, for instance the TEM cell (5).

Sections in the first part of (5) describe performances obtained in two large underground tunnels in solid granite which were chosen as examples of low-Q enclosures. The results indicate better correspondence with open air performance than is normally achieved in a conventional shielded enclosure.

Out of a short discussion of this finding arose the suggestion that the structure nearest to Malvern likely to give a similar performance was not a rocky cavern but one of the aircraft hangars on the RSRE site near Pershore. On the strength of this suggestion the empirical investigation to be described was undertaken. The objective was to carry out an electric field strength measurement using a particular equipment layout in three different locations in turn, viz the open air, a shielded enclosure and a large, almost empty, hangar.

The frequency range chosen, 10 to 110 MHz, is important because it is one in which there is a considerable investment in rf communications equipment including mobile and man portable equipments. There is therefore a strong demand for effective EMC control in this range.

EQUIPMENT AND LOCATIONS USED

The rf emission-generating, measuring and recording equipment comprised the following items:-

Hewlett Packard Spectrum Analyser consisting of:-

141T	Display Section
8552B	IF Section
8553B	RF Section

Hewlett Packard Tracking Generator/Counter, 8443A

Singer Instrumentation Biconical Antenna (20-200 MHz) Model 94455-1, Quantity 2.

Bryans X-Y Recorder, Type 26050

Double Screened RF Coaxial Cable, 20 ft long, Singer Instrumentation 90933-8, Quantity 2.

Coaxial Attenuator, 50 ohm, 10 dB nominal attenuation.

At the three locations in turn this equipment was arranged as illustrated in Fig 1. Horizontal or vertical polarisations were used as required. The antennae were arranged parallel, their centres 100 ± 1 cm apart and 150 ± 1 cm above the supporting ground or floor. (An aerial separation of 100 cms ± tolerance is frequently specified for EMC emission tests.) The attenuator

inserted in the coaxial outlet from the tracking generator, ensures that this output remains well matched over the swept frequency range irrespective of any frequency dependence of the antenna input impedance. The receiving antenna was connected via the other coaxial cable directly to the input of the spectrum analyser of which the Scan and Vertical Deflection outputs of the IF Section were connected to the X and Y inputs respectively of the recorder.

The spectrum analyser settings were:-

Bandwidth	10 kHz
Frequency Sweep	10 to 110 MHz
Scan Mode	Single shot
Scan Time	10 seconds/division
Scan Width	10 MHz/division
Output Mode	Logarithmic

Tracking generator output was set at 0 dBm (ie 1 mW) and would retain this value at all frequencies swept, the generator having been built to produce an rf signal of controlled and constant amplitude with its frequency at the centre of the movable passband of the associated analyser. Thus when the analyser frequency scans, the generator scans in sympathy. After manual initiation of the scan, the recorder (refer again to Fig 1) produces a plot (in dB μV against MHz) of the response of the system in its particular surroundings to a signal of 1 mW into 50 Ω sweeping from 10 to 110 MHz at the output of the tracking generator. (The analogy of such a set up to a communication link is clear.)

The further items involved in this comparative experiment were the open air site, the shielded enclosure and the hangar. These are described in the following three paragraphs.

The open air site was well clear of large buildings or other possible reflectors. It was an area at RSRE South from which the unobstructed sky is visible down to low elevations in most directions.

The shielded enclosure was the larger compartment, No: S3981D, of a two compartment Belling Lee enclosure. The dimensions in metres of this compartment are:- 6.1 x 3.66 x 3.05 high. The smaller compartment, immediately alongside and separated by a shielding partition, housed the emission generating/receiving/recording equipment with the exception of the two dipoles, the two 20 ft rf cables and the 10 dB attenuator which were in the larger compartment. Interconnection was completed via two bulkhead connectors in the partition and two additional short rf cables. The two antennae were placed centrally in their compartment along its lengthwise bisector with the appropriate separation. The compartment was free of all material other than the two antennae, their connecting cables and the attenuator, apart from 8 electric light fittings, the intruding portion of a small air exchanger and minor electrical fittings (switches, sockets etc) on the walls. Fig 8 is a photograph of the aerial arrangement in the compartment.

The hangar was H1 at RSRE Pershore. Its approximate dimensions in metres are:- 80 x 40 x 10 high. The antennae were located equidistant from a point on the plane bisecting the hangar width. The orientation of the antenna to antenna horizontal to the above plane was 0^{o}, 90^{o} or 45^{o} as described later. The distance of the antennae from the sliding doors at the nearer end of the hangar was about 17 metres. Fig 9 is a photograph taken from just inside these hangar doors showing the antennae in the foreground, in vertical

polarisation and in the 0^{o} orientation to the width bisector along which they stand. Also shown is the small amount of stored equipment including vehicles which remained inside the hangar during the experiments. These extraneous items had insignificant effect upon the shapes of the plots obtained (confirmed by moving some items).

RESULTS

Figs 2 and 3 are copies of the recordings obtained using, respectively, vertical and horizontal polarizations in the three locations. It is clear that in each polarization the hangar performance deviated much less from that in the open air than did the shielded enclosure performance. The latter shows deviations with modulus as great as 38 dB (vertical pol) and 26 dB (horizontal pol). Table 1, described by its caption, shows the contrast in performance in a more general manner. It indicates, for example, that for any electric

	DECIBELS										
	0	3	6	9	12	15	18	21	24	27	30
Vertical Pol	%	%	%	%	%	%	%	%	%	%	%
Shielded Encl	100	73.5	38	21.5	14	8.5	5	1.5	1.1	0.9	0.5
Hangar	100	0.5	-	-	-	-	-	-	-	-	-
Horizontal Pol											
Shielded Encl	100	67	43.5	21.5	14	9	3.5	1	0.5	-	-
Hangar	100	20	1	-	-	-	-	-	-	-	-

Table 1 - Percentages of the whole test frequency range (10 MHz - 110 MHz) over which modulus of deviation from open air value $>$ that stated at column head for shielded enclosure and hangar in both polarizations.

field strength measured in the shielded enclosure (in 10 kHz bandwidth in the range 10 to 110 MHz) the probability that the result would be at least 6 dB different from that similarly obtained in the open air was 38% or 43.5% according to polarization and that when similarly measured in the hangar the corresponding probabilities were 0% and 1%. Further conclusions can be extracted for each of the minimum deviation values indicated in dB at the column heads. The table shows that the hangar results lie much closer to the open air results than do the shielded enclosure results. This is further demonstrated by the rms deviations of the shielded enclosure and hangar readings from those of the open air shown in Table 2. These were extracted by inspection of Figs 2 and 3 and refer to the whole range 10 to 110 MHz.

Some further observations were made in the hangar to see whether big changes in the direction of propagation would reveal any useful data.

	dB
Vertical Pol	
Shielded Enclosure	8.7
Hangar	1.0
Horizontal Pol	
Sheilded Enclosure	8.3
Hangar	2.3

Table 2 - Showing rms deviations from the open air results over 10 - 110 MHz

Figs 4 and 5 show the result when the antennae were set on a line at right angles to the length of the hangar (indicated by the label 90°) and Figs 6 and 7 concern a line at 45° to the length. (All were centred on the same point about 17 metres from the end door of the hangar, antenna separation and height were maintained constant.)

By visual inspection we gather from these recordings that there were no substantial changes in the performance when using vertical polarization ie the hangar behaved much the same for 0°, 45° and 90° orientation of the antenna - antenna line. With horizontal polarization and 45° orientation there appears to have been some reduction in the deviations relative to the open air plot. It is considered that this observation contributes to a theory that the fairly large deviations obtained in the hangar with horizontal polarization at 0° antenna - antenna line (Fig 3) are due to resonances set up in structural members (eg ribs inside the roof, Fig 9) which lie parallel to the direction of polarization. One might reason that these effects are minimised with a 45° antenna to antenna line.

COMMENT AND CONCLUSIONS

It is not intended to seriously attempt theoretical explanations of the details of these results. It may be possible to comment usefully in this respect at a later date. It is widely believed that the high reflectivity of enclosure walls is a responsible factor setting up standing waves and consequent resonances to produce results akin to those described.

The behaviour of the hangar in approximating more closely to the open air over the frequency band tested may be merely a matter of size, internal reflections may be attenuated by distance (ie by spread within a solid angle) and consequently be less troublesome. If this is so then a very large shielded enclosure should behave similarly to the hangar. The hangar, however, has a characteristic not strongly possessed by a shielded enclosure, that is it is lossy (not having been deliberately intended as a shielded enclosure). Such losses could be due to the sum of several causes:-

The floor is of reinforced concrete and therefore lossy.

The walls are of metal sheets but these are unlikely to be in good electrical contact.

The walls contain a small area of glass windows which could allow leakage of radiation.

The doors are of a sliding variety and do not provide a gapless, conducting fit. They could therefore cause ohmic loss and permit radiation loss.

It is concluded that whatever the explanations may turn out to be a possible worthwhile use for an aircraft hangar no longer devoted to its conventional use would be as a dry and wind protected location within which to carry out EMC testing. Results obtained over frequency bands of interest are likely to approximate to open air results and this is considered a desirable characteristic.

A suitably large shielded enclosure is likely to have similar characteristics to a similar sized aircraft hangar. Some doubt is introduced by the fact that an enclosure will have smaller losses than a hangar. The facts should therefore be ascertained by experiment should the opportunity present itself. It is to be noted that should losses be found desirable these can be conveniently produced within an enclosure by the use of electromagnetic energy absorbent materials which are commercially available.

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APPENDIX

SOME TECHNICAL TERMS USED, DEFINITIONS

Electromagnetic compatibility (EMC): The ability of electrical and electronic systems, subsystems and equipments to share the electromagnetic spectrum and perform their desired functions without unacceptable degradation from or to the (electromagnetic) environment in which they exist.

Susceptibility: The unacceptable response or malfunction of systems, sub-systems or equipments when subject to electromagnetic energy.

Radiated emission: Desired or undesired electromagnetic energy in space.

Radiated interference: Undesired radiated emissions.

Field strength: The amplitude of a radiated emission at a point in the far field as indicated by a rms measurement of electric or magnetic component.

Electric field strength or magnetic field strength: The amplitude of a radiated emission at a point in the near field as indicated by a rms measurement of electric or magnetic component.

Note: In general the amplitude contains components proportional to $1/D$, $1/D^2$ and $1/D^3$ (where D = propagation distance). At large distances the $1/D$ term may predominate at short distance the $1/D^3$ term may do so. The near field zone is that where $1/D^3$ predominates, the far field is where $1/D$ does so.

An EMC measurement: A measurement made for an EMC purpose by a method prescribed for EMC purposes.

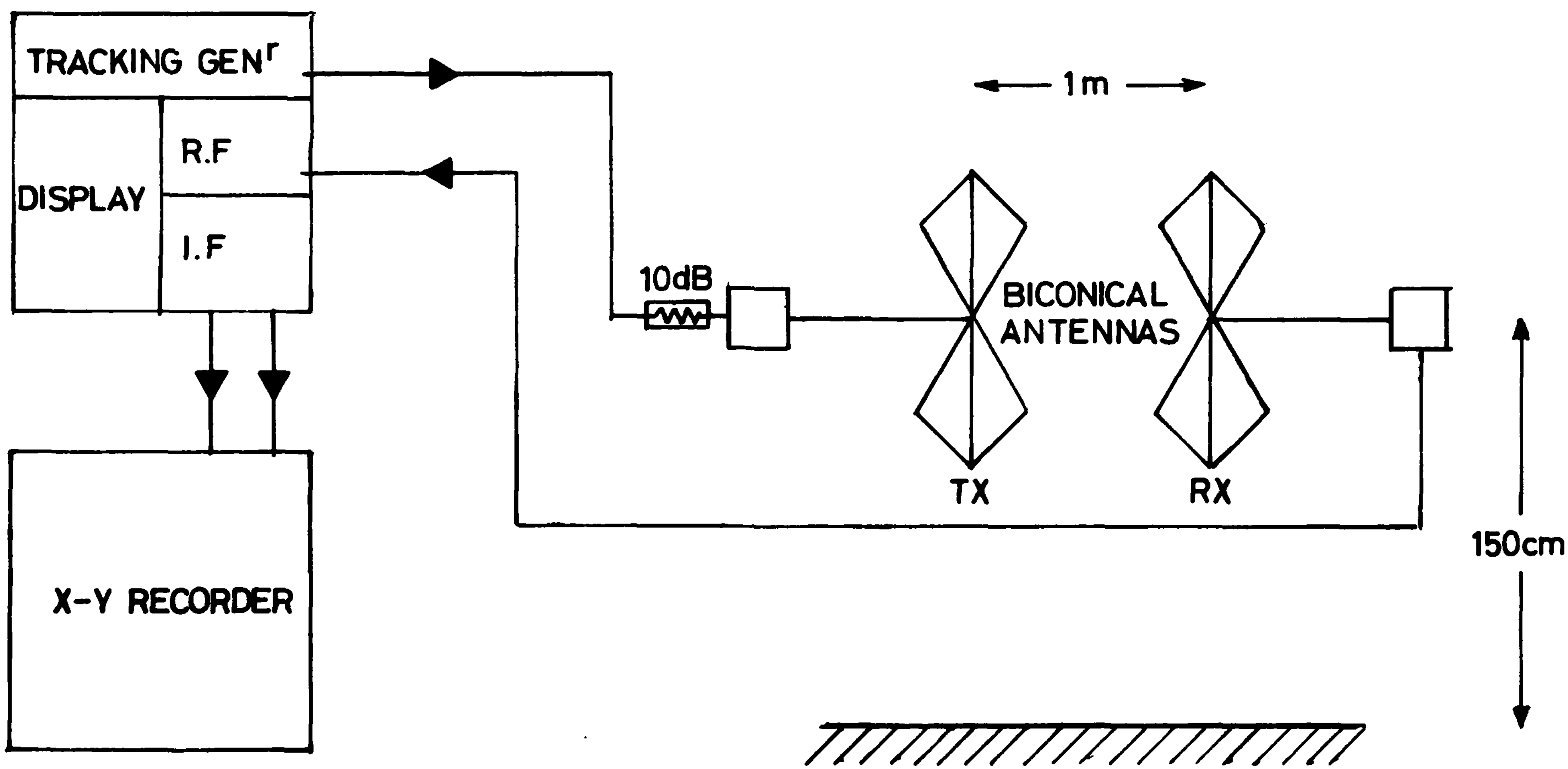
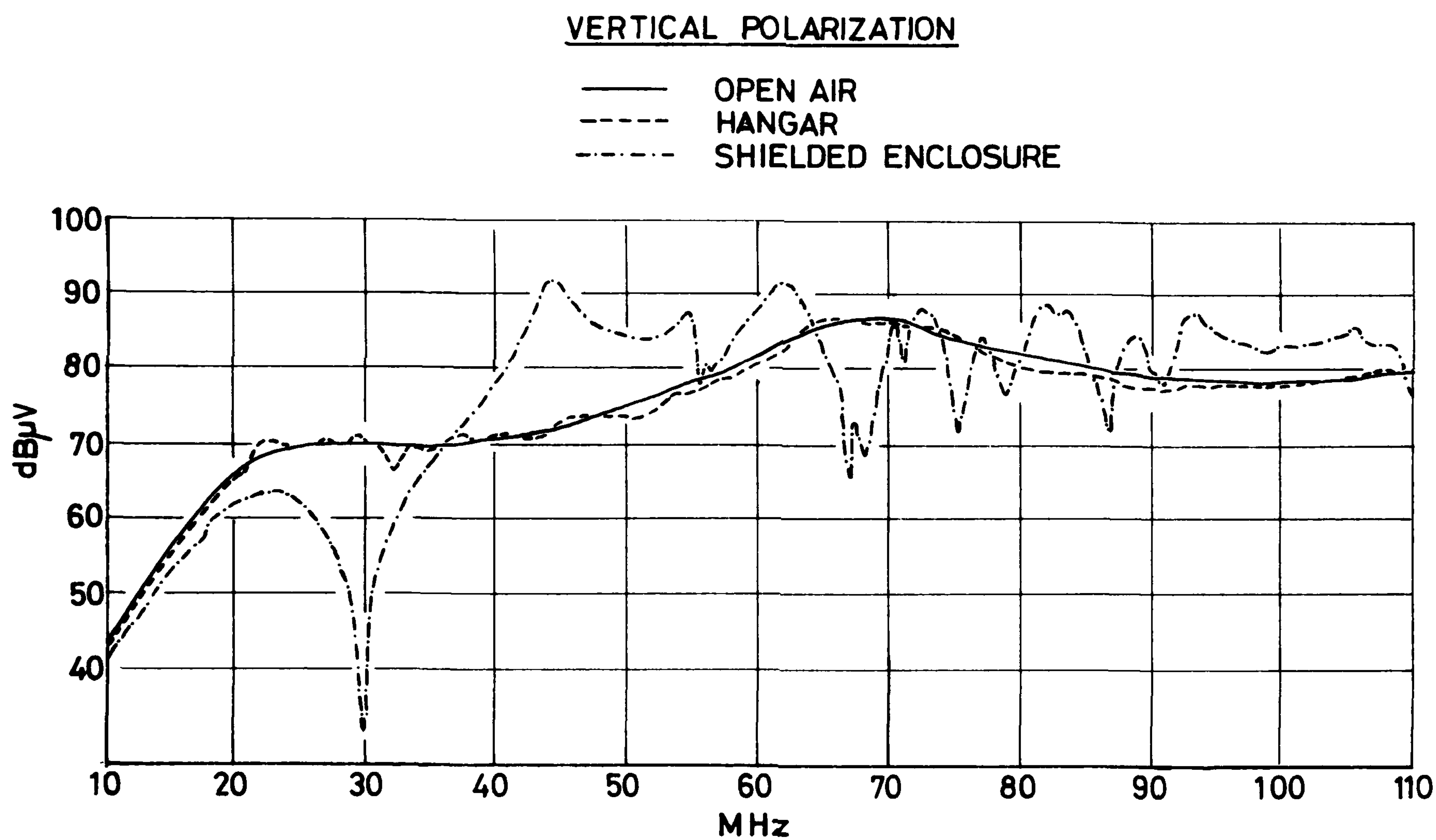

TRACKING GEN^r
DISPLAY
R.F
I.F
X-Y RECORDER
10dB
1m
BICONICAL ANTENNAS
TX
RX
150cm

FIG.1



VERTICAL POLARIZATION
OPEN AIR
HANGAR
SHIELDED ENCLOSURE
100
90
80
70
60
50
40
dBμV
10
20
30
40
50
60
70
80
90
100
110
MHz

FIG. 2

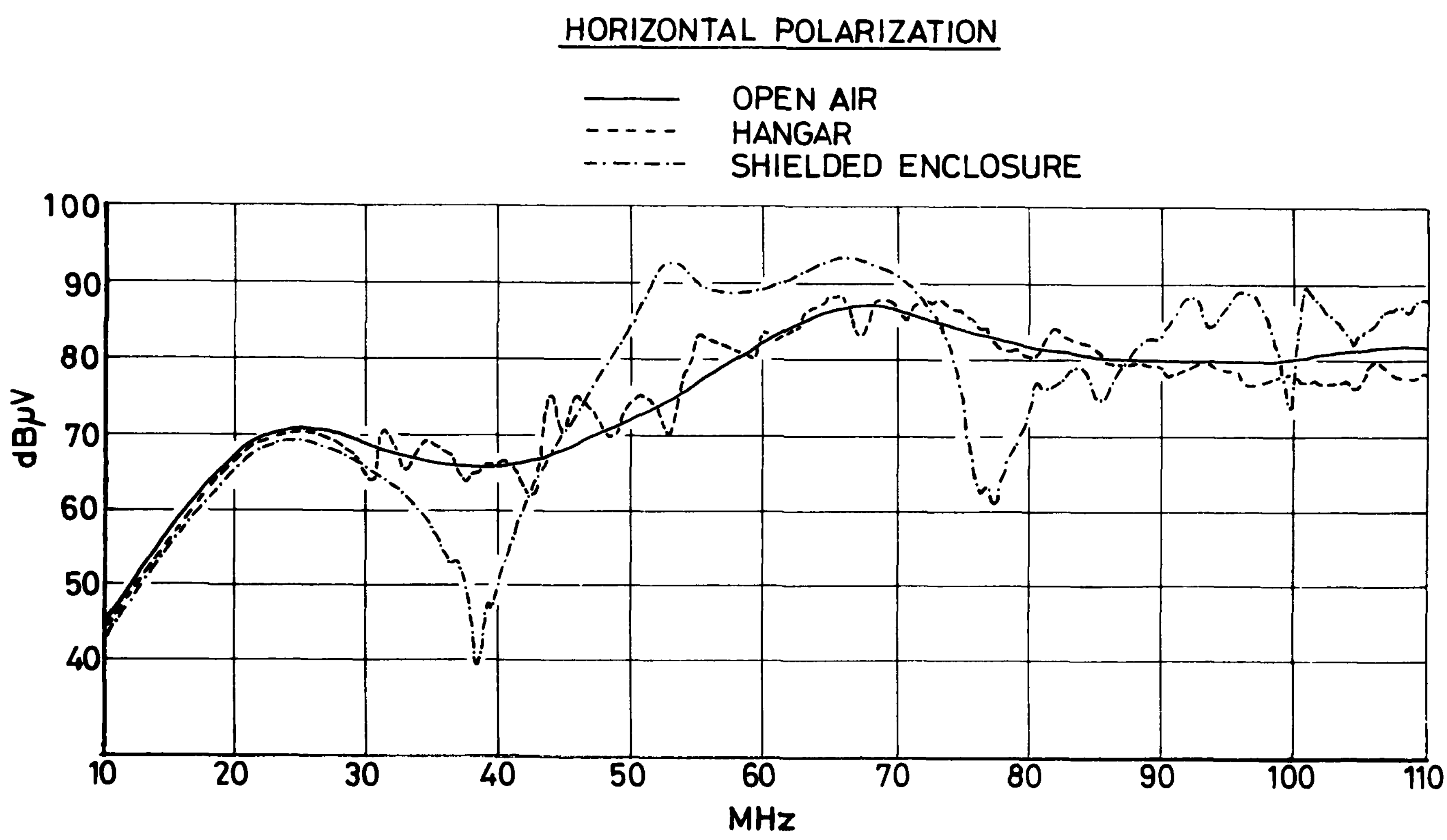
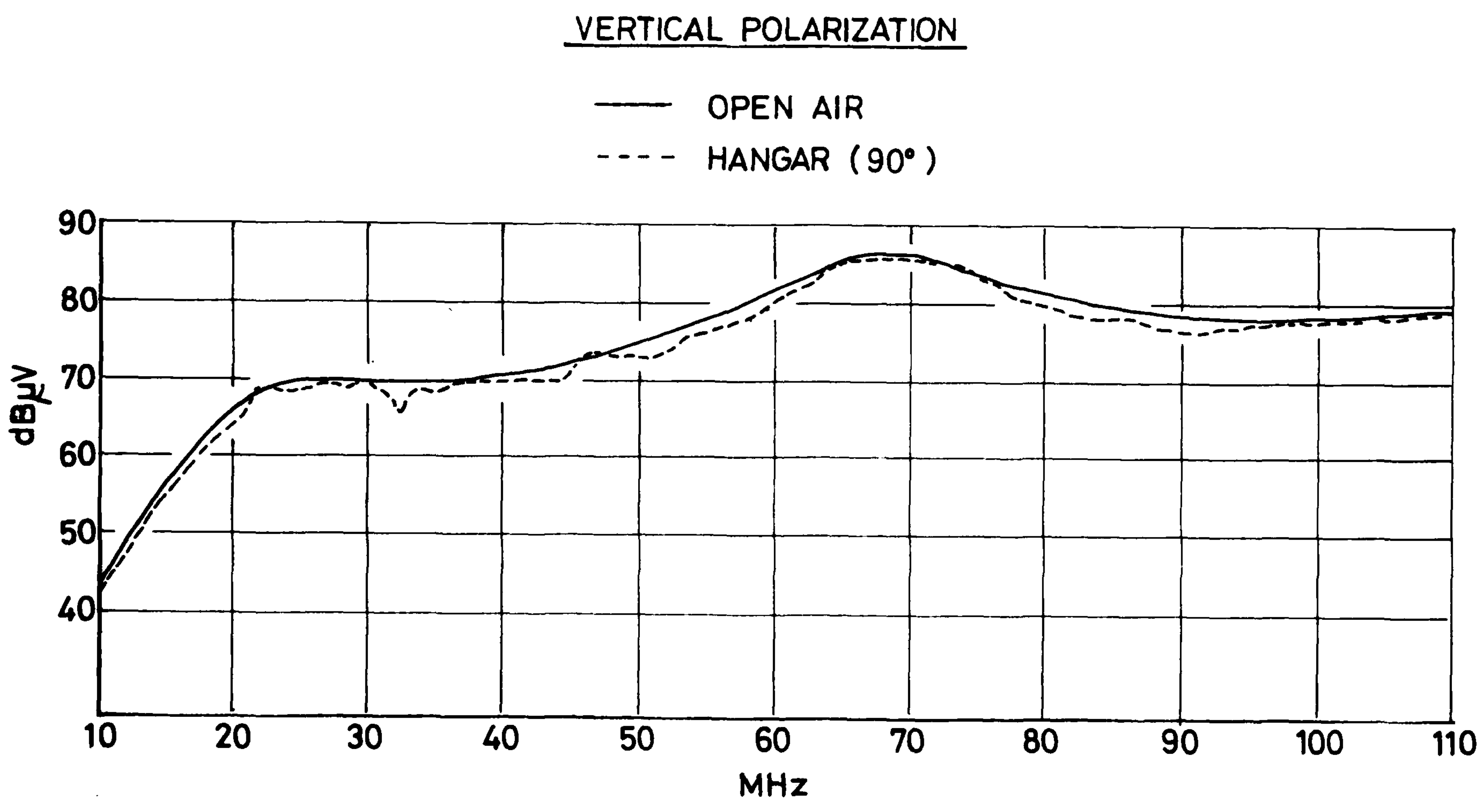
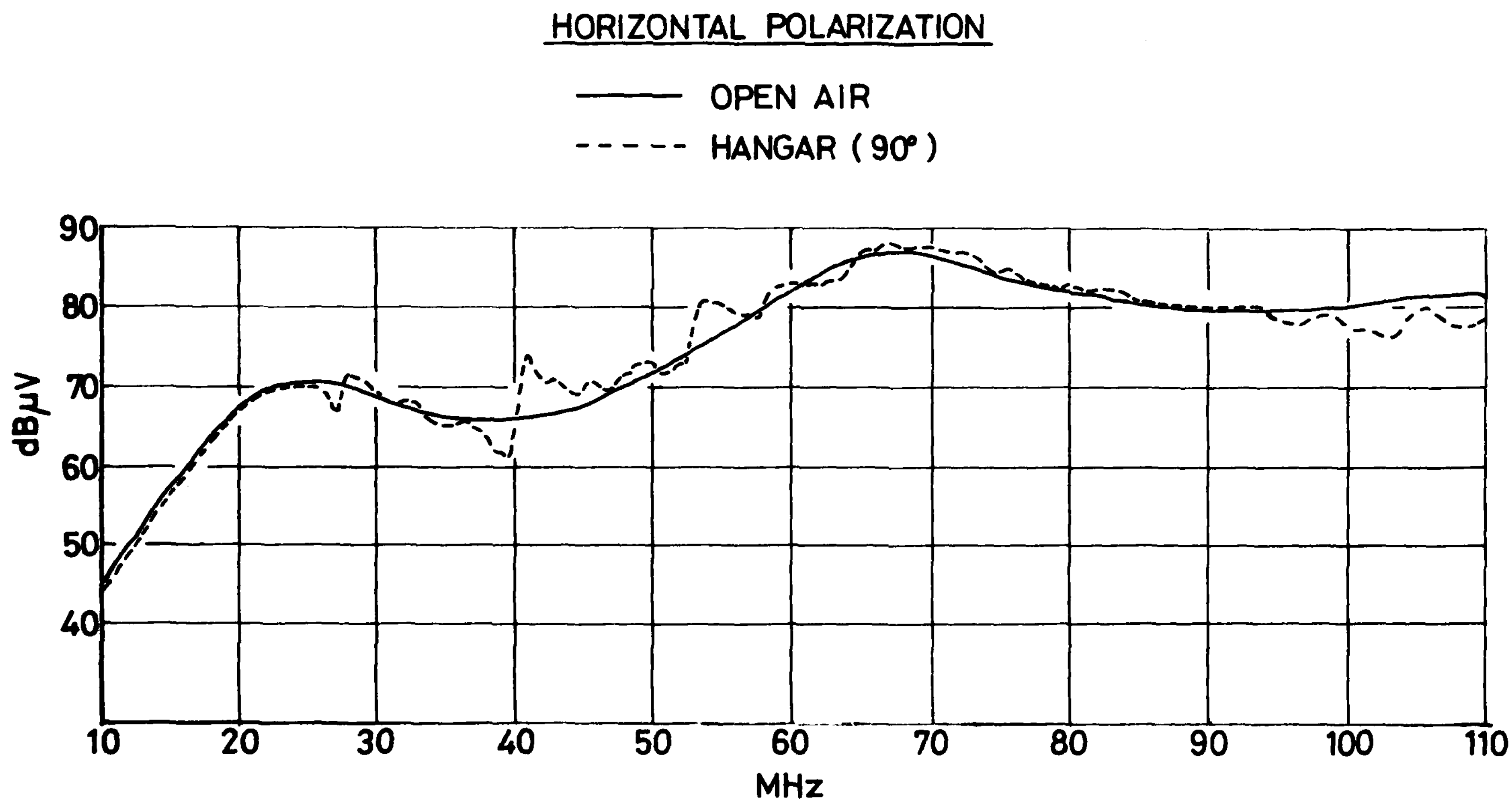

HORIZONTAL POLARIZATION
OPEN AIR
HANGAR
SHIELDED ENCLOSURE
100
90
80
70
60
50
40
dBμV
10
20
30
40
50
60
70
80
90
100
110
MHz

FIG. 3



VERTICAL POLARIZATION
OPEN AIR
HANGAR (90°)
dBμV
90
80
70
60
50
40
10
20
30
40
50
60
70
80
90
100
110
MHz

FIG.4


HORIZONTAL POLARIZATION
OPEN AIR
HANGAR (90°)
dBμV
90
80
70
60
50
40
10
20
30
40
50
60
70
80
90
100
110
MHz
FIG.5

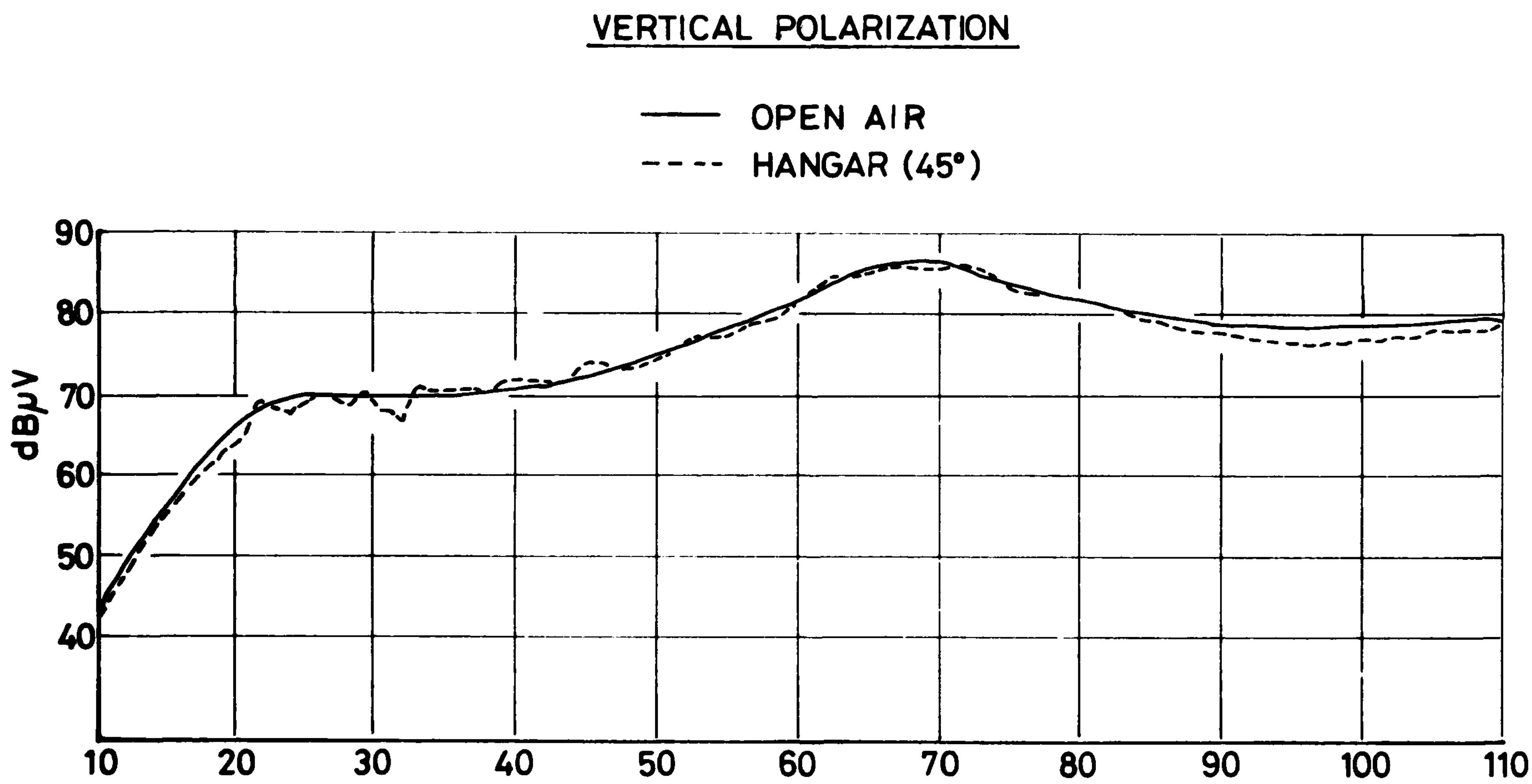

VERTICAL POLARIZATION
OPEN AIR
HANGAR (45°)
90
80
70
60
50
40
dBμV
10
20
30
40
50
60
70
80
90
100
110
MHz

FIG.6

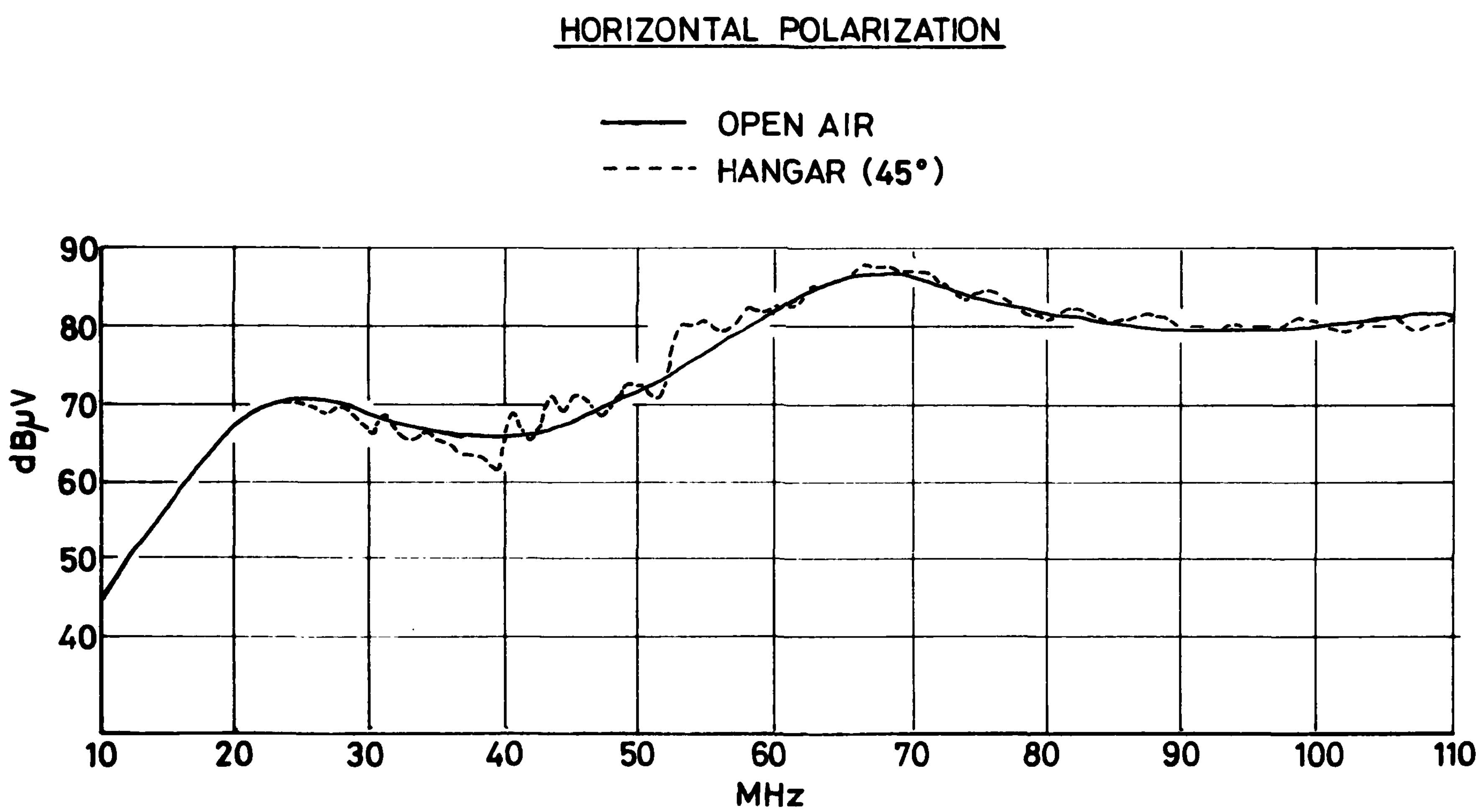

HORIZONTAL POLARIZATION
OPEN AIR
HANGAR (45°)
90
80
70
60
50
40
dBμV
10
20
30
40
50
60
70
80
90
100
110
MHz

FIG. 7

FIG. 8

INSIDE THE SHIELDED ENCLOSURE

FIG. 9

INSIDE THE HANGAR

DATE
ILMED
8